

Overview of Chapter 3

- ✧ Introduction
- ✧ Applicability and Scope
- ✧ Developing a QAPP
- ✧ Performing Field Activities
- ✧ Sampling Procedures for Area Screening

e3.0 Introduction

This chapter presents default methods available to screen source areas at a site. IDEM recognizes that these default methods may not be appropriate or feasible at some sites. However, use of the default methods will facilitate regulatory interchange and approvals. IDEM will consider other (nondefault) screening methods that better address site-specific conditions (see [Chapter 7](#)).

The purpose of screening by chemical sampling and analysis is to determine if additional investigation is warranted for a particular media. If a site is known to be contaminated, area screening may provide preliminary information needed to focus the site investigation. The most appropriate approach to screening will ultimately depend on site-specific factors and conditions. One default procedure for screening surface soil requires composited random samples from the entire potential source area. Another default method for surface soil identifies contaminated areas based upon judgement and site knowledge. The default procedure for subsurface soil focuses on finding the most severely contaminated areas to determine if further investigation is necessary.

The process for screening ground water at a site differs somewhat from soil screening requirements. Because ground water is mobile, it is difficult to determine if an individual sample was collected from a highly contaminated part of the ground water plume or from areas of lesser contamination. Because of ground water's mobility, if chemicals of concern are detected at any concentration, the nature and extent of the constituent plume must be characterized. Plume characterization may be completed using any appropriate technology; it does not necessarily require the installation of permanent monitoring wells. In addition, not all activities listed in Chapter 4 may be necessary for ground water plumes.

3.1 Applicability and Scope

Area screening is an optional activity. Screening is appropriate when contamination levels are unknown at a particular area. Screening should be conducted to determine which areas do or do not contain Contaminants Of Concern (COC) at concentrations that exceed default closure levels (see [Appendix 1](#)). If site media contain COCs at concentrations that exceed default closure levels, the user may forego area screening and instead proceed either to a determination of the nature and extent, or to remediation, of site contamination.

The default area screening approach is designed for soil COC source areas no larger than ½ acre. For individual soil COC source areas larger than ½ acre, the user may wish to consider employing nondefault screening methods (see Chapter 6). Using default methods to screen soil COC source areas that are larger than ½ acre may be inappropriate (see US EPA Soil Screening Guidance for limiting factors).

RISC includes a unique two-step procedure for combining screening and nature and extent of contamination steps in subsurface soils at a petroleum release site. The RISC User's Guide provides more details of the procedure.

In many cases area screening may be the first site investigation that includes the collection and analysis of waste and environmental samples. Sample locations should be selected strategically to best identify any COCs present at the site and to determine if COCs are affecting specific media (such as surface soil, subsurface soil, and ground water). Sample locations should also be selected strategically to determine if susceptible areas (such as geological, ecological, or wellhead protection areas) are likely to be affected.

Area screening requires three activities:

- Developing a Quality Assurance Project Plan (QAPP) that includes data quality objectives (DQO), a health and safety plan (HASP), a sampling and analysis plan (SAP), and a data quality assessment (DQA) (see [Section 3.2](#))
- Performing field activities and sampling procedures for surface soil, subsurface soil, and ground water (see [Section 3.3](#))
- Evaluating potential exposure concentration (PEC) screening data (see [Section 3.4.4](#))

Area screening should not be conducted if it will impede the responsible mitigation of acute environmental hazards. If an acute hazard is identified, it must be addressed immediately (see Section 2.2). Protection of human health and the environment is paramount. Addressing acute hazards expeditiously also typically reduces subsequent remediation costs. For example, in the case of a recent release or spill, expeditious remediation is often the most cost-effective and lowest-risk response strategy. The immediate excavation of soil affected by a chemical spill may prevent subsequent ground water contamination and degradation of resources. Nevertheless, a quick response to an acute hazard is only one step in

site closure. The user must still demonstrate that all remaining contamination was delineated and addressed within programmatic requirements.

A QAPP is a complete and detailed description of the location, collection method, type, and number of samples required for the field investigation. As such, a QAPP must include all information needed to collect data and samples at the site. It should also provide a defensible and detailed description of all activities, quality specifications, and precautions associated with sample collection, handling, and analysis. A complete, well developed QAPP minimizes the health risks, liability, and costs associated with sampling errors.

At a minimum, a QAPP must contain the four components listed in Table 3-1.

Table 3-1. Elements of a QAPP

Element	Description
DQO	DQOs establish the type, quality, and quantity of data required to make and defend a particular decision. They are developed using a seven-step planning process (see Table 3-2).
HASP	The HASP advises workers of site-specific health and safety concerns and outlines procedures to prevent or minimize injuries and illnesses.
SAP	The SAP specifies elements of the required field work and associated laboratory analysis. The SAP describes the media to be sampled as well as sampling locations and methods. It must also specify the quantity, depth, and quality control requirements for samples (such as matrix spike and duplicate sample requirements). In addition, the SAP identifies the quality assurance/quality control (QA/QC) measures of site sampling-related activities.
DQA	A DQA must be conducted to ensure that the QAPP is implemented as prescribed. DQA involves assessing the effectiveness of sampling implementation and QA/QC measures.

3.2 Developing a QAPP

Minimum Elements of a QAPP

- ✧ DQOs
- ✧ HASP
- ✧ SAP
- ✧ Sampling methods and requirements
- ✧ Sample custody requirements
- ✧ Analytical methods and requirements
- ✧ QA/QC and requirements
- ✧ Instrument and equipment testing, inspection, and maintenance requirements
- ✧ Instrument calibration and frequency
- ✧ DQA

The amount of detail required for each of the QAPP elements will vary by site and project. Projects of a limited scope or small aspects of larger projects may require only minimal information in the QAPP. Projects of significant duration or effort are likely to require more information. In such cases, an expanded QAPP may be required to ensure that the field investigation and laboratory analyses are well planned and properly conducted to achieve the project goals.

QAPP development is an ongoing procedure throughout the investigative and sampling process. Each time new sampling needs are identified, the appropriate elements of the QAPP (such as DQOs) should be modified to address the needs and concerns associated with the next sampling event and assessment. For area screening, the QAPP may be simple and brief. For a complicated, multiple COC, nondefault site assessment, the QAPP may be quite complex.

Many requirements for sampling and analysis are incorporated into the RISC guidance for area screening and characterization of the nature and extent of contamination. Relevant RISC guidance should be incorporated into the appropriate elements of the QAPP. The following subsections briefly discuss each element of the QAPP highlighted above (see Table 3-1). Additional discussion regarding characterizing the nature and extent of site contamination is included in [Chapter 4](#).

3.2.1 Data Quality Objectives (DQO)

IDEM prefers that users apply the EPA-established DQO process for all sampling performed in support of RISC. IDEM used the DQO process to develop the RISC screening procedures. By following these procedures, the DQO process will be satisfied for the screening evaluations.

Table 3-2 on the following page presents an overview of the DQO process applied to surface soil screening under RISC.

Contaminant characterization involves assessing and determining qualitative and quantitative aspects of the site. Qualitative aspects typically involve determining where contamination exists, with advanced planning to locate areas of potential contamination. Quantitative aspects involve determining COC concentrations and any associated risks.

Table 3-2. DQO Process Applied to Surface Soil Screening

Step	Description
1. State the Problem	Identify areas of the site where contaminated surface soils may pose a risk to human health.*
2. Identify the Decision	The decision is to determine if the mean surface soil concentration exceeds closure levels for specific chemicals of concern within potential source areas. If contaminant concentrations exceed closure levels, further investigation is required (see Chapter 4).*
3. Identify Inputs to the Decision	<ul style="list-style-type: none"> ■ Exposure inputs, such as ingestion, dermal contact, and fugitive dust inhalation rates* ■ COC concentrations* ■ Analytical methods (which should also be addressed in the SAP) ■ Default closure levels and applicability* ■ Quality assurance concerns (which should also be addressed in the QAPP)
4. Define the Boundaries	<ul style="list-style-type: none"> ■ Define the potential source area ■ Identify potential surface soil COCs ■ Classify the site as follows (see Section 2.9): <ul style="list-style-type: none"> ■ Areas unlikely to be contaminated ■ Areas known to be contaminated ■ Areas that may be contaminated <p>Define potential source areas and pathways</p>
5. Develop a Decision Rule	<p>The following decision rule applies for screening tests:</p> <p>If the mean constituent concentration within the potential source area exceeds the screening level, further investigation is required.*</p>
6. Specify Limits on Decision Errors	Specify the limits on decision errors, which are used to establish performance goals for limiting uncertainty in the data. IDEM provides default error limits in the Max and Chen tests (see Section 3.4).
7. Optimize the Design for Obtaining Data	<ul style="list-style-type: none"> ■ Identify the most resource-effective sampling and analysis design for generating data that will satisfy DQOs ■ Finalize the SAP, including statistical sampling design, sampling methods, and analytical methods* ■ Finalize the QAPP and provide sufficient detail on each QAPP element

* These aspects have been incorporated into the default screening procedures

Quantitative aspects also involve estimating the level of uncertainty, which helps the user understand and control the probability of making an incorrect decision based on the data. An incorrect decision within the DQO process may mean deciding not to collect more data, when in fact more data is needed. Alternately, an incorrect decision may involve deciding to collect more data, when source area constituent concentrations are actually less than default closure levels.

DQOs must be designed to address a wide array of questions regarding the site, the COCs, and the nature and extent of contamination. Typical questions DQOs are designed to answer include the following:

- Does contamination exist at a site?
- Does the mean constituent concentration in a particular potential source area exceed screening levels?
- What is the horizontal and vertical extent of contamination?
- What volume and type of media contains COC concentrations that exceed closure levels?
- Does the contamination pose risks to human health or the environment?
- Did remediation reduce constituent concentrations in affected media to less than the closure levels?
- What are the soil characteristics in the potential source area?

The DQO process is recommended for additional site characterization and data collection for nondefault closure scenarios. The DQO process may be applied separately for each media and potential source pathway. Developing DQOs for multiple pathways, media, or COCs may require working through the process several times for each source area.

Site characterization under RISC is based on the identification and assessment of DQOs. EPA recommends the use of DQOs and has published extensive guidance on this topic. Certain programs, such as Superfund, have specifically adopted the DQO process as a requirement. For additional EPA guidance on DQOs, consult Appendix 6 and the following:

- EPA. September 1993. *Data Quality Objectives Process for Superfund, Interim Final Guidance*. EPA/540/R-93/071, PB96-963203.
- EPA. December 1994. *Soil Screening Guidance: Technical Background Document, Review Draft*. EPA/540/R-94/106, PB96-963532.

3.2.2 Health and Safety Plan (HASP)

The HASP is a written document included as part of the QAPP (in RISC). The HASP details field activities conducted in compliance with IDEM and OSHA requirements. The HASP should be completed by a competent professional with appropriate training and experience. The plan must comply with the requirements of 29 CFR 1910.120.

3.2.3 Sampling and Analysis Plan (SAP)

After DQOs are established for each type of required sampling, the user should prepare a SAP. The SAP should be designed to ensure that sample collection activities produce samples and analytical data that meet the needs established in the DQOs.

The SAP identifies where samples will be collected, usually by locating them on the conceptual site model or detailed site map. The SAP should provide details of the specific methods and equipment used to collect and handle samples in the field, and it should identify the appropriate field or laboratory methods to be used to analyze each sample.

Procedures for sampling environmental media are well documented. *The Compendium of Superfund Field Operations Manual* (EPA 1987) and other relevant documents identify demonstrated field sampling methods and techniques.

Analytical methods (see [Appendix 2](#)) should be carefully selected and should consider the advantages and disadvantages of field versus laboratory analysis for the data quality needs of the decision. Methods listed in SW 846, the EPA Contract Laboratory Program (CLP), and the *Methods for the Determination of Organic Compounds in Drinking Water* are used most commonly. Superfund sites are required to use CLP procedures.

3.2.4 Quality Assurance/Quality Control (QA/QC)

The SAP in the QAPP must include a QA/QC program. The QA/QC portion describes the policy, organization, functional activities, and protocols necessary to achieve DQOs dictated by the intended use of the data. These elements are defined in the preceding references.

Agency-wide QA/QC requirements are listed in [Table 3-3](#).

For additional details on analytical requirements, see the discussion of estimated quantitation limits (EQL) in [Appendix 2](#). For program-specific QA/QC requirements, the IDEM document, *Guidance to the Performance and Presentation of Analytical Chemistry Data* references the appropriate analytical determinations and requirements (IDEM 1998).

3.2.5 Data Quality Assessment (DQA)

DQA involves assessing the effectiveness of the sample design, sampling procedure, and laboratory analysis. DQA is used to ensure that the sampling and analytical quality are adequate to meet the precision, accuracy, representativeness, comparability, and completeness (PARCC) requirements established in the DQOs. DQA identifies the review process needed to support project requirements and confirms that the field sampling QA/QC event, the field documentation, and the QA/QC samples provide useable data. DQA also evaluates the final results of the site investigation and compares them to the closure levels. Figure 3-1 describes the DQA process.

3.3 Performing Field Activities

Before performing any field activities, it is essential to determine the type of environmental media requiring investigation as well as the most appropriate classification for the site. This section defines the types of environmental media and site classifications available under the RISC default closure scenario.

3.3.1 Types of Environmental Media

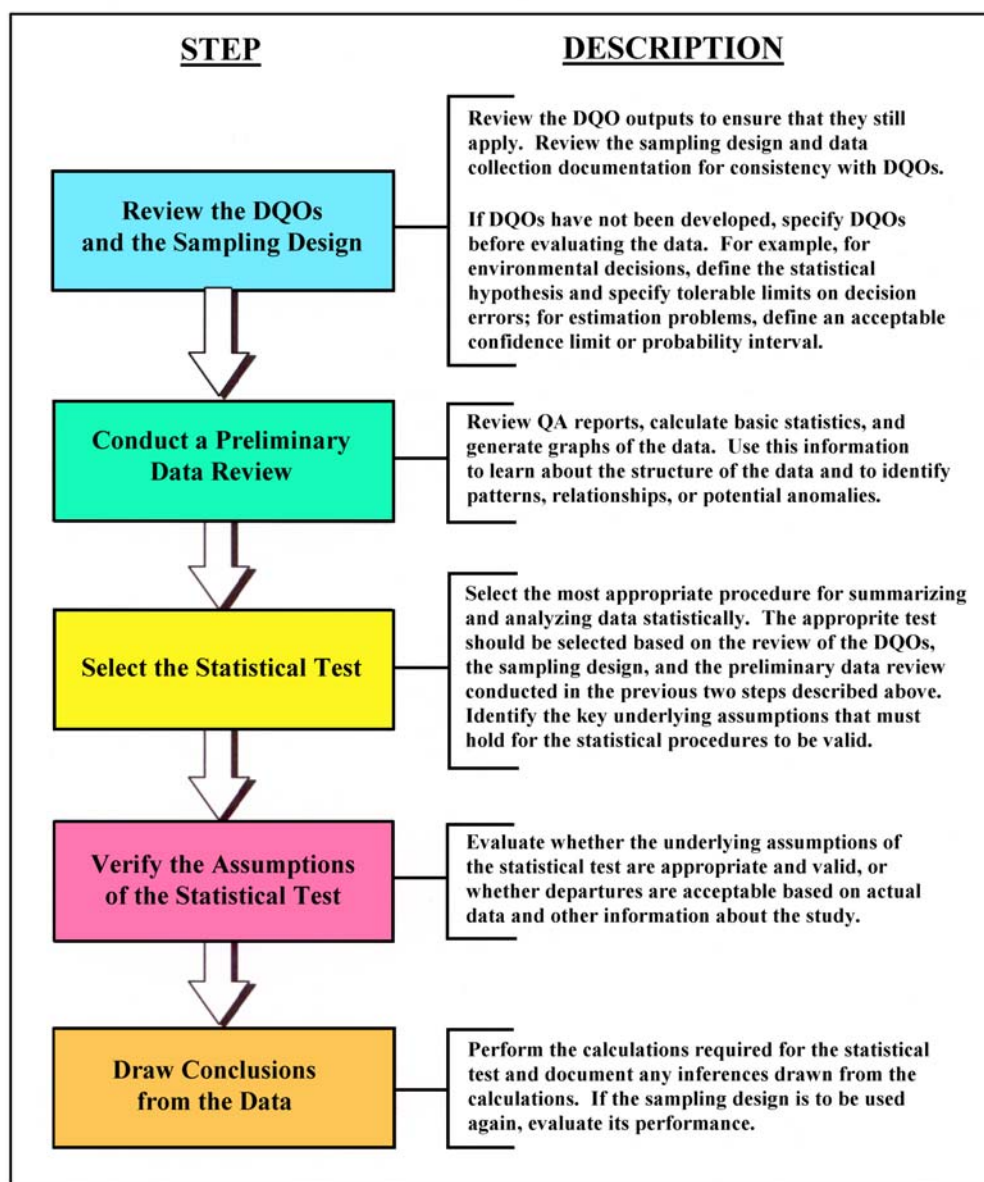
Default area screening tests were developed using DQOs for three categories of media: surface soil, subsurface soil, and ground water (see Figure 3-2).

- Surface soil is defined as the top 6 inches of soil. Any surface soil sampling conducted under RISC must be representative of the top 6 inches of soil at the site.

Table 3-3. QA/QC Requirements

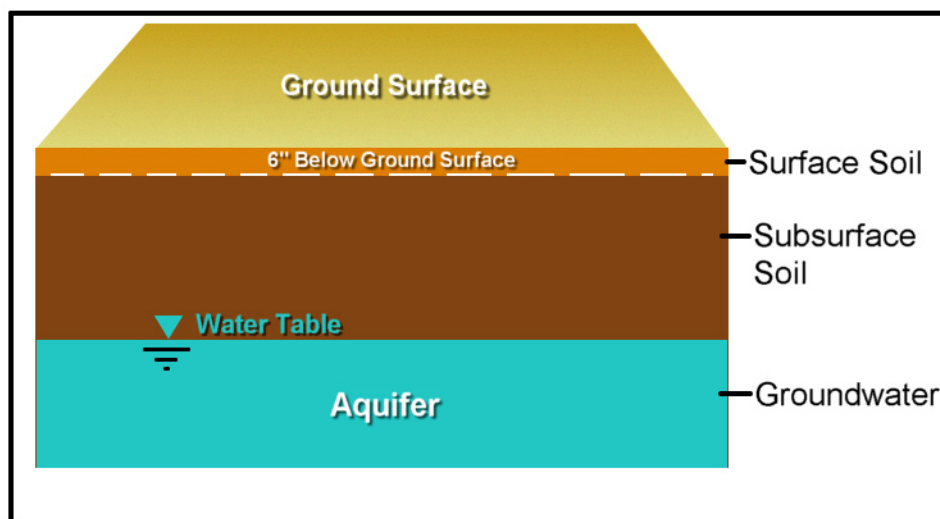
Minimum Sampling QA/QC Requirements
Chain-of-custody form
Date and time each sample was collected
Map indicating sampling locations
Documentation of any field measurements and notable observations
Use of equipment blanks and trip blanks
Use of field duplicates, matrix duplicates, and matrix spike duplicates
Laboratory Required QC Information
Completed chain-of-custody form
Date and time of receipt
Sample condition upon receipt
Sample identification number
Sample preparation, extraction, cleanup, or digestion method
Analytical method
The precision, accuracy (or bias), representativeness, comparability, and completeness (PARCC) requirements for each target analyte (including calibration requirements)
Analytical results, including appropriate level of laboratory data quality deliverables
Case narrative indicating any deviations from standard analytical procedures
Corrective action criteria for any deficiencies noted by a review of QA/QC procedures and the DQA

Figure 3-1. The DQA Process



- Subsurface soil is defined as soil in the interval extending from 6 inches below the surface to the water table. Subsurface soil sampling should not include the smear zone, which may be present at the water table.
- Ground water is defined as water that exists at saturation in the interstitial voids of soil or rock.

Figure 3-2



The smear zone represents the seasonal limits of ground water fluctuation (that is, the top of the water table). The smear zone is not sampled for area screening purposes. The soil-to-groundwater partitioning model used to calculate closure levels for migration to ground water only evaluates the *potential* for leaching from soil *above the water table*. Contamination in the smear zone may introduce more dissolved COC into the ground water, and this increase in contamination may result in plume stability test failure (see [Appendix 3](#)). In such cases, evaluating the smear zone and treating the source may be required to achieve plume stability.

3.3.2 Chemical versus Petroleum Sites

As previously noted, default area screening procedures under RISC are different for petroleum releases than for other chemical releases. A petroleum release site is one where product petroleum lubricating oil or fuel has been released. A chemical release site is one where other types of chemical contamination occurs. At petroleum release sites, such as a leaking underground storage tank (LUST) site, the type,

location, and source of contamination are often known. As a result, screening and determination of the nature and extent are combined during the investigation of subsurface soils. [Chapter 3](#) of the RISC User's Guide provides more information on Leaking Underground Storage Tank (LUST) sites. The identification and determination of the nature and extent of contamination at chemical release sites are rarely so well known or predicted. Because issues involved in chemical releases vary from site to site, this document outlines more appropriate assessment methods.

3.3.3 Classifying Site Areas Correctly

It is important to classify site areas correctly. Three classifications are available (see Section 2.9):

- Areas unlikely to be contaminated
- Areas known to be contaminated
- Areas that may be contaminated

Appropriate classification is essential to determine if COC concentrations in an investigated area exceed closure levels and to determine the next steps in the RISC process. Documentation of site area classification should be submitted for IDEM's review.

Table 3-4 outlines surface soil sampling procedures for the three area classifications. The procedures are presented for volatile and nonvolatile constituents. Default screening of source areas that may be contaminated must be limited to ½ acre. Larger areas may be partitioned into ½ acre source areas for surface soil sampling. In addition, the screening instrument must be demonstrated to be reliable and appropriate for the constituent.

3.3.4 Assessing Site Features

Before determining the most appropriate sample locations for screening a source area, significant features of the site and the site area should be assessed. In particular, background sampling locations should be determined, preferential pathways as well as erosional and depositional areas should be identified, and the surrounding vicinity should be evaluated for the presence of environmentally sensitive areas.

Table 3-4. Area Screening Tests for Surface Soils

Area Classification	Sampling Nonvolatile Compounds	Sampling Volatile/Nonvolatile Compounds
Areas unlikely to be contaminated	No investigation is required; however, documentation must support this classification. No closure document is issued for these areas.	
Areas known to be contaminated	Proceed to determination of the nature and extent of contamination; if the nature and extent are known, select a default or nondefault approach and proceed with closure.	
Areas that may be contaminated	<p><u>Max test</u></p> <ul style="list-style-type: none"> • Divide each source area into four sections • Take one random sample from each of the four sections to make one composite; repeat eight times for a total of eight composites • Compare the highest composite concentration value to 2 times the value in the default closure table (see Appendix 1) • Conduct DQA 	<p><u>Chen test</u></p> <ul style="list-style-type: none"> • Divide each source area into four sections • Take three random samples per section for a total of 12 samples; do not composite the samples • Follow the procedure for Chen test

3.3.4.1 Preferential Pathways and Surface Water Erosion and Deposition

If preferential pathways exist at a site (such as drainage tiles, karst features, utility conduits, or sand lenses), or if surface water erosional or depositional areas exist (such as gullies and flood plains), these areas should be identified and sampled if they could be affected by site COCs.

Preferential pathways may allow COCs to migrate beyond the potential source area of the site, possibly in unexpected directions. Because preferential pathways may transport COCs rapidly across long distances, these site features require special investigation and may require different sampling methods.

Erosional and depositional areas of surface water systems should be evaluated to determine if COCs that migrate off site are likely to be deposited in sediments or carried away from the site through surface water surges, floods, and scouring mechanisms.

3.3.4.2 Environmentally Sensitive Areas

The area surrounding the site should be investigated to determine if any sensitive off-site features exist. Sensitive features may include residential areas, residential and municipal wells, recreational areas, day care facilities, schools, play grounds, nursing homes, senior citizen centers, surface water systems, aquatic wildlife reproduction areas, endangered species habitats, or agricultural areas. Potential COC migration pathways should be evaluated; ultimately, sampling and analysis may be required.

3.4 Sampling Procedures for Area Screening

This section discusses the following sampling strategies and procedures that should be used when screening potential source areas for COCs:

- Determining sample locations
- Surface soil screening procedures
- Subsurface soil screening procedures
- Evaluating PEC soil screening data
- Ground water screening procedures

3.4.1 Determining Sample Locations

Selecting appropriate sampling locations is essential for evaluating chemical constituent concentrations at any site. Locations can be selected by random methods or by judgmental sampling. The purpose of the sampling is the most important consideration in selecting locations.

Two basic sampling methodologies are appropriate for collecting environmental samples: (1) **statistical** (Random Sampling) and (2) **judgmental** sampling. Most contamination in soils tends to be highly variable in its distribution. Therefore, if Simple Random Sampling is used to identify contamination in a large area, a large number of samples may be required to ensure that COCs are found and accurately characterized.

Distinct areas at a site may have different constituent concentrations or characteristics. For this reason, horizontal stratification of the site is necessary, and each source area should be evaluated individually. Statistical sampling is usually the best method when there is little information about an area or strata. This method may be varied to include systematic random sampling.

Details of statistical sampling methodologies and sample placement options can be found starting on page 102 of the EPA *Soil Screening Guidance: Technical Background Document* (1996).

Judgmental sampling may be appropriate when a great deal of information is available regarding site contamination. Judgmental sampling selects sample locations based on knowledge of the site and the physical or chemical characteristics of the known COCs. Determining locations for soil and ground water sampling is based in part on site history. Using judgmental sampling to investigate a site relies on any current and historical information sources that may provide site-related data on operations at the site.

Judgemental Positioning of Samples - Visual Assessment

If a site strata or area shows signs of contamination (unexplained stressed vegetation, staining, or other evidence), then a sample should be taken in the area that appears to be most contaminated. If a leachate seep is observed, there is probably a contaminated ground water plume. This situation would require sampling of both ground water and leachate. The plume should be delineated using the guidance in Section 4.4.2 for ground water characterization.

Horizontal Positioning of Samples

The first sample should be collected from the area suspected of having the highest COC concentrations in each known or potential source area. Additional sample locations should be selected to delineate the extent of the contamination and should progress outward from the source area until chemical concentrations are less than the default closure levels. At least one sample must be collected upgradient of the source area, and at least one sample must be collected from downgradient and each of the two side-gradient locations.

The following methods are available to determine the horizontal extent of contamination:

- Visual assessment
- Geophysical survey methods
- Soil gas surveys
- Push-probe devices
- Immunoassay screening
- Colorimetric field kits
- X-Ray fluorescence (XRF)
- Photoionization detector (PID) screening

- Flame ionization detector (FID) screening

Screening results must be recorded on the boring logs and field sampling sheets. Results of screening soil with the field methods listed above may or may not indicate the depth of contamination, and there may be no direct relationship between field screening and analytical results. Instead, the information generated from field screening should be used in conjunction with laboratory results to better evaluate the nature and extent of contamination.

The remainder of this section provides information on sampling objectives and volatile and nonvolatile sampling.

3.4.1.1 Sampling Objectives

The sampling objectives of screening are stated in the introduction to this chapter. Some additional considerations are listed below.

Because COCs can move through the soil and react with air and other soil constituents, multiple environmental media may require sampling to (1) identify the COC source area, (2) evaluate COC migration pathways, and (3) determine the chemical fate of the COCs (for example, how COCs may have reacted with soil, water and air constituents and the resulting products of such reactions).

Sampling is generally not required under buildings, paved roads, or other site features where it would cause significant destruction of the existing structures. In such cases, nondestructive methods can often be used to obtain samples in these areas. A Licensed Professional Geologist should evaluate and record soil boring cores.

3.4.1.2 Volatile and Nonvolatile Sampling

The primary difference between sampling for volatile and nonvolatile compounds is that volatile samples cannot be composited. In general, even for nonvolatile samples, unrestricted composite sampling and soil homogenization are not acceptable. Too much homogenization of composite samples collected over a large area tends to introduce a negative bias in the analytical results, possibly underestimating actual

COC concentrations. If compositing is to be used, the following limitations apply:

- Soil samples should never be composited or homogenized when they will be analyzed for volatile compounds, including total petroleum hydrocarbons. The physical act of mixing the sample will cause the loss of many volatile organic compounds.
- Soil samples collected for analysis of semivolatile organic compounds (SVOC), diesel fuel, pesticides, polychlorinated biphenyls (PCB), metals, and other analytes with low volatility may be suitable for restricted compositing.

Guidance on sampling procedures is available in *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies* (EPA 1992).

3.4.2 Surface Soil Screening Procedures

For both volatiles and nonvolatiles, the surface soil screening test for areas that may be contaminated is based on a statistical analysis of the data; site data are then compared to the appropriate default closure levels.

The strategy for nonvolatile COC sampling in areas that may be contaminated involves compositing samples across the entire source area. The ideal strategy for sampling surface soils would be to determine the true population mean of COC concentrations in the potential source area. However, determining the true mean would require extensive sampling and potentially high costs. As an alternative, the [Max Test](#) from the EPA Soil Screening Guidance is used. The [Chen Test](#) is used for volatiles, although it may also be used for nonvolatiles.

Data obtained from limited sampling will not perfectly represent the true mean at a site. Nevertheless, some uncertainty in the data is acceptable if the data are treated conservatively. The DQO process allows the degree of acceptable uncertainty in the sampling to be determined, thereby establishing a conservative yet reasonable approach. In essence, the DQO process sets limits on the probabilities of making an incorrect decision.

A decision (see Table 3-2) is usually defined in terms of whether or not to investigate the site further. Such a decision should be based on whether the potential exposure concentrations (PECs) in a source area exceed, or are less than, default closure levels as follows:

- If the site PECs exceed default closure levels, the nature and extent of contamination must be determined (see [Section 3.4.4](#)).
- If the site PECs are less than default closure levels, no further investigation is required. In such cases, the user may pursue closure if COC concentrations in other media in the area are also less than closure levels.

Incorrect decisions at a site can have two outcomes: (1) deciding that a site is not contaminated when it is (Type I error) and (2) deciding that a site is contaminated when it is not (Type II error). Both the Max and Chen tests are designed to limit these errors to at least a 5 percent probability of a Type I error and 25 percent probability of a Type II error.

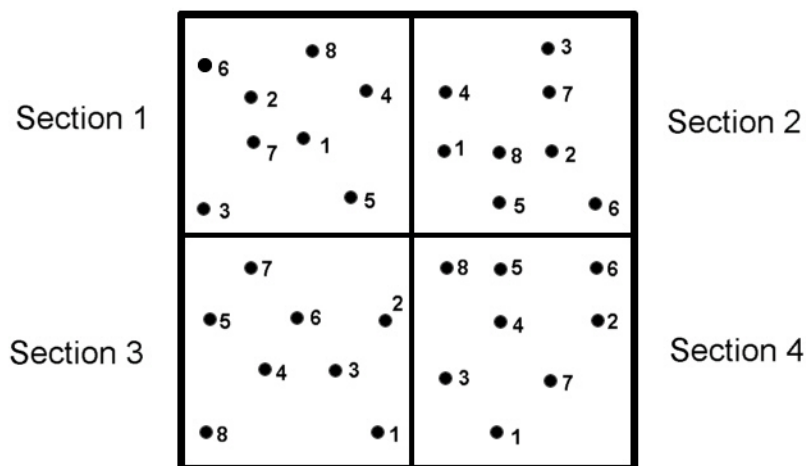
Guidance on selecting appropriate sampling procedures is available in the following EPA documents: *Soil Screening Guidance: Technical Background Document (1996)* and the *Soil Screening Guidance: Users Guide (1996)*.

3.4.2.1 Max Test for Nonvolatile Compounds in Areas that May Be Contaminated

The Max test is recommended for sampling surface soil for nonvolatile compounds in areas that may be contaminated. The Max test sampling strategy involves the following:

1. Divide the unknown area (up to ½ acre) into four sections, each roughly the same size.
2. Collect eight composite samples, each consisting of a discrete sample from each of the four sections delineated in Step 1 (see Figure 3-3).
3. Perform comparison testing.

Figure 3-3. Example Random Sampling Pattern



The text on the following pages provides specific procedures and examples for using the Max test to determine if a surface area is contaminated, when the chemical of concern is a nonvolatile compound.

Max Test General Procedure for Nonvolatile Compounds

1. Divide the potential source area into four sections covering a total of no more than a ½-acre area.
2. Repeat steps 2A to 2C eight times, to obtain eight composite samples (x_1 ..., x_8) (see Figure 3-3):
 - 2A. Take one random sample from each of the four sections.
 - 2B. Mix those four samples into one composite sample
 - 2C. Measure each COC concentration in the composite to yield x_i

The specific individual samples to be composited into one sample should be chosen at random (for example, with a random number table).

3. Compare the maximum value for each chemical from the eight composites with twice the default Closure Level (CL) for the chemical.
 - 3A. If the highest value for a chemical exceeds 2 times the CL for that chemical, the source area requires further investigation of the nature and extent of contamination.

- 3B. If the highest value for a chemical is less than the CL divided by the square root of the number of samples in each composite ($x_{\max} < CL / \sqrt{k}$), the surface soil is eligible for closure for that chemical.
- 3C. If the highest value for a chemical is less than 2 times the CL for that chemical, *and* it is greater than the CL divided by the square root of the number of samples in each composite, ($x_{\max} \geq CL / \sqrt{k}$), the evaluation is not complete. Proceed to Step 4.
4. Calculate the following to evaluate the sample size n :
- 4A. The sample mean of the eight composite sample concentrations, \bar{x} :

$$\bar{x} = \sum x / n, \quad \text{Where } n = 8 \text{ composite samples}$$

- 4B. The sample standard deviation, s :

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} = \sqrt{\frac{\sum x^2 - [(\sum x)^2 / n]}{n - 1}}$$

- 4C. The estimated coefficient of variation (CV) (EPA 1996):

$$CV = \frac{s\sqrt{k}}{\bar{x}}$$

Where k is the number of individual samples in each composite (in this case, $k = 4$)

- 4D. Use the following table to find the minimum number of composited samples required (n_{\min}) for various values of CV :

CV	1	1.5	2	2.5	3	3.5	4
n_{\min}	8	8	8	8	8	9	11

For CV values that fall between two values in the table, use the sample size for the next higher CV . The table is based on a four-specimen composite ($k = 4$).

5. Evaluate the CV as follows:

If $CV < 3.0$ and $n = 8$, the area may be eligible for surface soil closure for that COC.

If $CV > 3.0$ and $n \leq 8$, additional samples are required as indicated in the table above.

If $CV > 4.0$ and $n \leq 8$, contact IDEM for advice.

Reference: EPA. 1996. *Soil Screening Guidance: Technical Background Document*. Washington, DC, 20460, US Environmental Protection Agency, Office of Research and Development. Report No. 9355.4-17A; EPA/540/R-95/128; PB96-963502.

Example 1:

1. An area is sampled for arsenic, for which the default CL for surface soil in an industrial/commercial application is 19.6 milligrams per kilogram (mg/kg).
2. The eight composited samples (each a composite of one individual sample from each of four sub-areas) yield the following concentrations ($x_1 \dots, x_8$):

4.49, 4.29, 8.19, 2.70, 1.88, 0.83, 2.64, and 7.35 mg /kg

3. The largest of these, $x_{\max} = 8.19$, and the comparison value is :

$$2 \times \text{CL} = 2 \times 19.6 = 39.2$$

$$x_{\max} < 39.2,$$

Next, checking the sample size:

$$x_{\max} < \text{CL} / \sqrt{k}$$

In this case, $8.19 < 19.6 / \sqrt{4} = 9.8$

Because this condition is also met, this surface area may be eligible for surface soil closure for arsenic.

Example 2:

1. An area is sampled for arsenic, for which the default CL for surface soil in an industrial/commercial application is 19.6 mg/kg.
2. The eight composited samples (each a composite of one individual sample from each of four sub-areas) yield the following concentrations ($x_1 \dots, x_8$):

22.45, 21.45, 44.95, 13.5, 9.4, 4.15, 13.2, and 36.75 mg/kg

3. In this case, the maximum composite concentration, $x_{\max} = 44.95$ mg/kg, exceeds the comparison value of:

$$2 \times \text{CL} = 2 \times 19.6 = 39.2$$

Therefore further investigation is required, and a determination of the nature and extent of contamination is necessary.

Example 3:

1. An area is sampled for arsenic, for which the default CL for surface soil in an industrial/commercial application is 19.6 mg/kg.
2. The eight composited samples (each a composite of one individual sample from each of four sub-areas) yield the following concentrations ($x_1 \dots, x_8$):

11.23, 10.73, 20.48, 6.75, 4.7, 2.08, 6.6, and 18.38 mg/kg

3. In this case, $x_{\max} < 2 \times \text{CL}$ ($20.48 < 39.2$), so the first condition is met.

and

$$x_{\max} > \text{CL} / \sqrt{k}, \quad 20.48 > 9.8$$

Where $\text{CL} / \sqrt{k} = 19.6 / \sqrt{4} = 9.8$

Because $x_{\max} > \text{CL} / \sqrt{k}$, calculate for following:

$\bar{x} = 10.12$ (see Equation 4A) and $s = 6.4909$ (see Equation 4B), so

$$CV = \frac{s\sqrt{k}}{\bar{x}} = \frac{6.4909\sqrt{4}}{10.12} = 1.28$$

Evaluating using the CV Table, $CV = 1.28$, which is less than 3, and the number of samples per composite ($k = 4$) and the number of composite samples, ($n = 8$) match the table assumptions. Because this condition is also met, this area may be eligible for surface soil closure for arsenic.

3.4.2.2 Chen Test for Volatiles in Areas that May Be Contaminated

The Chen test is recommended for volatile compounds because it tests the same error rates in a statistically valid manner using single samples rather than composites. Composite samples are not appropriate for volatile compounds. The Chen test may also be used for nonvolatile compounds. The Chen sampling strategy involves the following:

1. Divide the unknown area (up to ½ acre) into four sections, each roughly the same size. If the Max test was used, the same areas delineated for the Max test may be used for the Chen test.
2. Take three random samples per section. Use sampling methods and equipment appropriate for the chemicals of concern, and do not composite the samples.
3. Follow the procedures and consult the examples provided in the text below and on the following pages to determine if the area requires further investigation.

Chen Test General Procedure for Volatile and Nonvolatile Compounds

1. Using all 12 samples, calculate the sample mean, $\bar{\theta}$:

$$\bar{\theta} = 3x / n ,$$

2. Calculate the sample standard deviation, s :

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} = \sqrt{\frac{\sum x^2 - \left[\left(\sum x \right)^2 / n \right]}{n - 1}}$$

3. Calculate a measure of skewness, b :

$$b = \left[\frac{n}{(n-1)(n-2)} \right] \frac{\sum (x - \bar{x})^3}{s^3} = \left[\frac{n}{(n-1)(n-2)} \right] \frac{\sum x^3 - 3\bar{x} \sum x^2 + 3\bar{x}^2 \sum x - n\bar{x}^3}{s^3}$$

4. Calculate the coefficient, a :

$$a = b / (6\sqrt{n})$$

5. Calculate the Student's t statistic, using the default CL (t):

$$t = \left(\frac{\bar{x} - \mu_0}{s} \right) \sqrt{n}$$

Where: $\mu_0 = 0.5 \text{ CL}$

6. Calculate Chen's t statistic (t_2):

$$t_2 = t + a(1 + 2t^2) + 4a^2(t + 2t^3).$$

7. Perform the t_2 evaluation, using a normal z value = 0.842:

7A. If $t_2 \geq 0.842$, then the surface area requires further investigation.

7B. If $t_2 < 0.842$, the area may be eligible for closure if a second condition is met:

The test must have adequate power to reject the null hypothesis when it is false (see Step 8).

$$n_{\text{power}} = 2.75 \left(\frac{s}{\text{CL}} \right)^2$$

8. To test for power, calculate the sample size (n_{power}) as follows, ensuring the required power:

8A. If n_{power} is smaller than the number of samples (n), then the surface area may be eligible for closure.

8B. If n_{power} is larger than n , then:

8B1. More samples should be taken to bring the total to at least n_{power} , and

8B2. Both tests should be repeated, based on the augmented data set.

Examples Using the Chen Test

Example 1:

Suppose the following measurements are obtained for benzene, for which the default CL for surface soil in an industrial/commercial application is 13 mg/kg (see Appendix 1).

Section 1	Section 2	Section 3	Section 4
6.6	20.7	56.3	8.4
18.1	11.1	73.1	16.9
5.0	7.9	33.0	23.1

1. Calculate the sample mean:

$$\bar{x} = \frac{\sum x}{n} = \frac{6.6 + 18.1 + 5.0 + 20.7 + 11.1 + 7.9 + 56.3 + 73.1 + 33.0 + 8.4 + 16.9 + 23.1}{12} = 23.35$$

2. Calculate the standard deviation:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} = \sqrt{\frac{(6.6 - 23.35)^2 + (18.1 - 23.35)^2 + (5 - 23.35)^2 + (20.7 - 23.35)^2 + (11.1 - 23.35)^2 + (7.9 - 23.35)^2 + (56.3 - 23.35)^2 + (73.1 - 23.35)^2 + (33 - 23.35)^2 + (8.4 - 23.35)^2 + (16.9 - 23.35)^2 + (23.1 - 23.35)^2}{12 - 1}}$$

$$s = 21.234$$

3. Calculate the measure of skewness (b):

$$b = \left(\frac{n}{(n-1)(n-2)} \right) \frac{\sum (x - \bar{x})^3}{s^3} = \left(\frac{n}{(n-1)(n-2)} \right) \frac{\sum x^3 - 3\bar{x} \sum x^2 + 3\bar{x}^2 \sum x - n\bar{x}^3}{s^3}$$

$$b = \left(\frac{12}{(12-1)(12-2)} \right) \frac{\left((6.6 - 23.35)^3 + (18.1 - 23.35)^3 + (5 - 23.35)^3 + (20.7 - 23.35)^3 + (11.1 - 23.35)^3 + (7.9 - 23.35)^3 + (56.3 - 23.35)^3 + (73.1 - 23.35)^3 + (33 - 23.35)^3 + (8.4 - 23.35)^3 + (16.9 - 23.35)^3 + (23.1 - 23.35)^3 \right)}{(21.234)^3} = 1.591$$

4. Calculate a :

$$a = b / \left(6\sqrt{n} \right) = \frac{1.5910}{6\sqrt{12}} = \frac{1.5910}{20.78} = 0.0765$$

5. Calculate t , where $\mu_o = 0.5 \times CL$:

$$t = \left(\frac{\bar{x} - \mu_o}{s} \right) \sqrt{n} = \left(\frac{23.35 - 0.5(13)}{21.234} \right) \sqrt{12} = \frac{58.37}{21.234} = 2.749$$

6. Calculate the Chen's t_2 statistic:

$$t_2 = t + a(1 + 2t^2) + 4a^2(t + 2t^3)$$

$$t_2 = 2.749 + 0.0765(1 + 2 * 2.749^2) + 4 * 0.0765^2 * (2.749 + 2 * 2.749^3) = 5.0204$$

7. Evaluation: Because $t_2 = 5.0$ is greater than 0.842, the area requires further investigation and a determination of the nature and extent of contamination.

Example 2:

Suppose the following measurements are obtained for benzene, for which the CL is 13 mg/kg (see Appendix 1).

Section 1	Section 2	Section 3	Section 4
2.2	6.9	18.9	2.8
6.1	3.7	24.5	5.7
1.7	2.6	11.1	7.7

- Steps 1 through 6 For these data, the statistics are calculated as in the example above and have the following values:

$\bar{0} = 7.825$, $s = 7.1256$, $b = 1.5881$, $a = 0.0764$, $t = 0.6441$, and $t_2 = 0.812$, with $\Phi_0 = 6.5$.

7. Evaluation: $t_2 = 0.812$, and $0.812 < 0.842$, so the sample concentrations appear to be less than the contamination threshold of 6.5 mg/kg.
8. Calculate n_{power} :

$$n_{power} = 2.75 \left(\frac{s}{CL} \right)^2 = 2.75 \left(\frac{7.1256}{13} \right)^2 = 0.826.$$

Evaluation: The 12 samples are clearly adequate to ensure the specified power (12 > 0.826) for the Chen test, so both conditions are met. Hence, the area may be eligible for surface soil closure, although investigation of other media should continue.

3.4.3 Subsurface Soil Screening Procedures

The purpose of subsurface soil screening is to try to find the most severely contaminated areas and evaluate whether further investigation is warranted. Screening subsurface soils is usually less complex than screening surface soils, but in many cases, it is more important. Subsurface soil closure levels are often the "driver" of a cleanup.

The default model used to develop closure levels is based on a source area no greater than ½ acre. Source areas larger than ½ acre require nondefault closure evaluations and may require different sampling procedures (see Chapter 7).

A simple default procedure for determining the size of the source area is to measure the length of the longest distance between soil borings where COC concentrations are less than or equal to the default closure levels. This length is then squared, and the resulting area should be compared to the area of $\frac{1}{2}$ acre (21,780 ft²). Alternately, actual configuration of the contaminated area can be used to calculate the size of the source area.

The screening procedure for subsurface soils does not include a determination of the nature and extent of soil contamination. The extent of contamination is determined after the screening tests. Nevertheless, it is wise to keep in mind source size considerations while performing screening.

Subsurface soils should be sampled at areas of known contamination, based on the surface soil sampling and other information (such as visibly stained soils, knowledge of previous site activities, or knowledge of buried COC sources). Samples should be collected at locations within the source areas that are expected to have the highest COC concentrations. In general, three borings in a $\frac{1}{2}$ -acre source area meet screening needs. In a smaller area, fewer borings may be adequate.

Proper evaluation of subsurface soil characteristics requires taking a continuous soil core from the ground surface to the depth of interest. In almost all cases, the core should extend to the water table. Obtaining a soil core to the depth of the water table allows for a thorough evaluation of the relationship between the properties of the COC and the properties of the soil. When the soil core has been thoroughly evaluated, the representativeness of samples taken from it can be assessed.

The soil evaluation consists of a description of the source area and soil features based on the following:

- Visual and tactile observation
- Field tests or measurements that involve relatively simple procedures and equipment
- Methods for collecting undisturbed or minimally disturbed samples for physical, chemical, and microbiological characterization (where appropriate) in the laboratory

Subsurface sampling has three goals: (1) to identify the depth at which contamination begins and ends, (2) to evaluate the presence of

preferential pathways to ground water, and (3) to quantify the level of contamination. Sampling that meets these goals makes it possible to determine if the source area poses a potential risk that requires further investigation. This approach requires that soil samples quantify COC concentrations from the ground surface to the depth where concentrations are less than the land use-specific closure levels. For both volatile and nonvolatile subsurface sampling, a ground water sample should be collected from each boring (see [Section 3.4.5](#)).

3.4.3.1 Sampling Subsurface Soils for Volatile Compounds

The default procedure for collecting subsurface soils where volatile compounds are present consists of four steps:

1. Take three soil borings in areas with the highest suspected COC concentrations.
2. Use a field instrument (such as a photoionization detector or flame ionization detector) to field-screen each 2-foot sampling increment to determine the highest reading within the boring.
3. Collect a sample from the increment with the highest reading and submit it for laboratory analysis.
4. Compare the average of the three soil boring samples to the default closure guidelines. If more than 3 borings are sampled, use the average of the three highest samples.

Another option for volatile sampling in subsurface soil is to calculate a weighted average. [Section 3.4.4](#) provides more information on PECs.

Additional guidance on the procedures and statistical evaluations is available in the EPA publications: *Soil Screening Guidance: Technical Background Document* (1996) and the *Soil Screening Guidance: Users Guide* (1996).

3.4.3.2 Sampling Subsurface Soils for Nonvolatile Compounds

The default method for screening subsurface soil for nonvolatile substances is based on a thorough evaluation of the soil stratigraphy and type. A general overview of the default procedure for selecting sample locations within a soil core is outlined below in a four-step process. The overview is not comprehensive and does not discuss sampling procedures. The discussion below provides a basic

understanding of the subsurface sampling approach for nonvolatiles that IDEM considers acceptable and appropriate. In instances when these default methods are not appropriate, the site must be evaluated using nondefault methods.

■ **Step 1 - Obtain a Soil Core**

Soil cores are usually obtained using a push probe, split-spoon, or similar technology. Several sampling methods are available, and almost any generally accepted method of obtaining undisturbed or minimally disturbed soil cores may be appropriate.

■ **Step 2 - Evaluate the Soil Core**

The primary activities involved in evaluating the soil core include identifying the soil strata and describing the soils. The USDA Soil Texture Classification System and the “Description and Sampling of Contaminated Soils” (EPA/625/12-91/002) provide a framework for this process. Not all of the information recommended in these documents may be required at every source area; conversely, additional information may be required for some. At a minimum, Munsell soil charts should be used to evaluate and describe the soil color, and observations should include texture, consistence, structure, inclusions, and boundary characteristics. Additional information on sample equipment and handling is also typically recorded.

■ **Step 3 - Collect Field Measurements**

When they are available for the chemicals of concern, appropriate field instruments and measurements can provide extremely useful information for the selection of sample locations. The instrument or method *must* be appropriate for the constituents being evaluated.

Field measurements should be used to find locations within the soil core that appear to contain the highest constituent concentrations. Locations with the highest apparent constituent concentrations should be sampled *in addition to* other appropriate locations determined based on the stratigraphy and constituent characteristics. Use of field instruments may ultimately reduce the total number of samples required.

There are generally two distinct objectives for performing field measurements: (1) to gather health and safety information to monitor safe working conditions at the site and (2) to quantify the concentration of constituents present in site media. Field instruments do not generally provide the level of accuracy required for quantification. Although they can be used as an aid in this process,

they cannot constitute the only analytical method. Nevertheless, when used properly, these instruments can help simplify the sampling process.

■ **Step 4 - Selection of Stratum-Based Sample Points**

In almost all cases it will be necessary to collect stratum-based samples for nonvolatiles, especially when a field instrument is not available, does not detect COCs, or does not detect COCs in a range that provides reasonable instrument accuracy. The basis for selecting sample locations must be provided to IDEM.

Appropriate Sample Intervals and Locations

- Sample locations should be chosen to represent the most contaminated area at the site. The following conditions typically indicate that a location may be appropriate for sampling:
- **Visibly Stained Soil** — Soil that is discolored, oily, shiny, or visibly altered should be sampled.
- **Likely Soil Strata** — Soil samples should be chosen to focus on the most likely location of the COC in the soil core, based on the COC characteristics and soil type. Typical considerations include the potential accumulation of metals in clay or silt, accumulation on the top of clay strata or at the bottom of sand strata, or other locations *based on the expected behavior of the COC in the environment*.
- **Sample Points Within A Stratum** — The selection of sample locations within a soil stratum varies with COC and soil characteristics. Thin layers of interbedded material caused by depositional cycles may often be treated as a single stratum, although additional samples may be required. Strata thicker than 6 inches are generally sampled individually. The number of samples in a thick stratum may vary. One sample in a 2- to 3- foot stratum is probably adequate, but a thicker stratum may require two to three samples, depending on the soil type and the COCs.
- **Topography** — Many times the topography will provide useful information for locating areas of potentially high COC concentrations. For example, runoff areas, depressions, and other low-lying areas may have accumulated chemicals from nearby source areas.

- **The Smear Zone** — The soil column must be evaluated carefully to identify the smear zone. The smear zone is the area between the top of the water table at its highest level and the top of the water table at its lowest level. Because COCs in the smear zone may have already leached to ground water, this area is not considered when evaluating leaching potential. The smear zone can sometimes be identified by soil staining, a visible change from oxidized soil to reduced soil, or other visual means; in some instances, other methods may be needed. In areas with very shallow ground water, it may be necessary to modify sampling procedures. Both of these situations will generally require a nondefault evaluation of site soil and ground water.

3.4.4 Evaluating Potential Exposure Concentration (PEC) Soil Screening Data

The PEC is the constituent concentration in surface and subsurface soil that is either representative of the site mean (based on random sampling), or the highest concentrations at the sample location (based on judgmental sampling). PECs are calculated from screening, nature and extent and closure sample analyses for comparison with corresponding closure levels for both direct soil contact and migration to ground water. Default closure levels are listed in the Default Closure Table (see [Appendix 1](#)). The sampling process generates a PEC for each constituent within each of the sampled media. Within the default approach, PEC soil screening analytical data must be evaluated as follows:

Surface soil

1. Volatile constituents
 - Statistical sampling methods - utilize the Chen test
 - Judgmental sampling methods - compare each sample analytical result to the appropriate closure level
2. Nonvolatile constituents
 - Statistical sampling methods - utilize the Max test, or use the Chen test for better information on where the constituents are located
 - Judgmental sampling methods - compare each sample analytical result to the appropriate closure level

Subsurface soil (judgmental)

1. Volatile constituents

- Follow the procedure outlined in chapter 3.4.3.1 for sample collection (steps 1-3) and PEC evaluation (step 4).
- 2. Nonvolatile constituents
 - Follow the procedure outlined in chapter 3.4.3.2 for sample collection
 - Using only analytical results from strata with detections, average the data within each boring. If the intervals are not all of the same length, then the calculation of the average concentration must account for the different lengths of the intervals - see EPA Soil Screening Guidance Technical Background Document chapter 4.2.8.
 - Compare each boring analytical average to the appropriate closure level(s)

If all PECs for a source area are less than default closure levels, no further action is necessary with respect to the source area. If any PECs at a site exceed default closure levels, the nature and extent of site contamination must be determined for each COC that failed the screening test (see [Chapter 4](#)).

3.4.5 Ground Water Screening Procedures

Where volatile compounds are detected at any concentration in the soil, ground water screening or a determination of the nature and extent of ground water contamination must be completed (see RISC User's Guide for exceptions). A minimum of one boring is required within each source area. At least one ground water sample should be taken from each boring. Push-probe technology is suitable for acquiring ground water screening samples.

In all cases where one of the following conditions exist, ground water samples must be collected:

- The site geology may allow COC migration through a preferential pathway to the water table.
- Highly permeable soil conditions exist at the site.

If the conditions above do not exist, and the only site COCs are nonvolatile, ground water sampling may not be necessary if either of the following is true:

- The water table is extremely deep.

- Subsurface soil is not contaminated to the water table; that is, at least two consecutive stratigraphy-based increments comprising at least four feet of clean soil are present at the base of the boring.

If a nonvolatile COC is detected in ground water, the nature and extent of ground water contamination must be determined (see [Chapter 4](#)).